THE EARLY PRE-CAMBRIAN FORMATIONS OF NORTHERN ONTARIO AND NORTHERN MANITOBA

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The classification of rocks earlier than the Cambrian is one of the difficult problems of geology. Correlation from point to point rests largely upon lithology and upon the succession of lithological units, and difficulties arise both from original similarity of formations of quite different age, and from similarity through the developments of the same metamorphic minerals in rocks originally of quite different character. Correlation is especially difficult in formations of early pre-Cambrian time, since these have undergone much longer periods of deformation than have the later ones. Varying successions of these early rocks have been worked out in some detail in different parts of the Canadian shield, and many attempts have been made to formulate a generalized succession that will fit all areas. None of these attempts has been successful, since the determination of the age of a formation by its likeness to a certain formation as described in an accepted classification, is liable to lead to quite erroneous conclusions. A review of some areas in western Ontario and northern Manitoba will show the diversity in various sections and will, it is believed, make possible certain generalizations.

RAINY LAKE DISTRICT

The first attempt to subdivide the early complex was made by Lawson[1] in the Rainy River district. He recognized two formations earlier than the first granite intrusion. The lower of these is his *Coutchiching series*, which he believes to be the oldest formation in the area. The Coutchiching rocks consist of mica

[1] *Geol. Survey of Canada, Ann. Rept.*, New Series, Vol. III, Part I (1887–88).

DISTRICTS

Rainy Lake	1
Porcupine	2
Abitibi	3
Lake Nipigon	4
NW. Manitoba	5
Wekusko L.	6
Cross Lake	7
Knee Lake	8

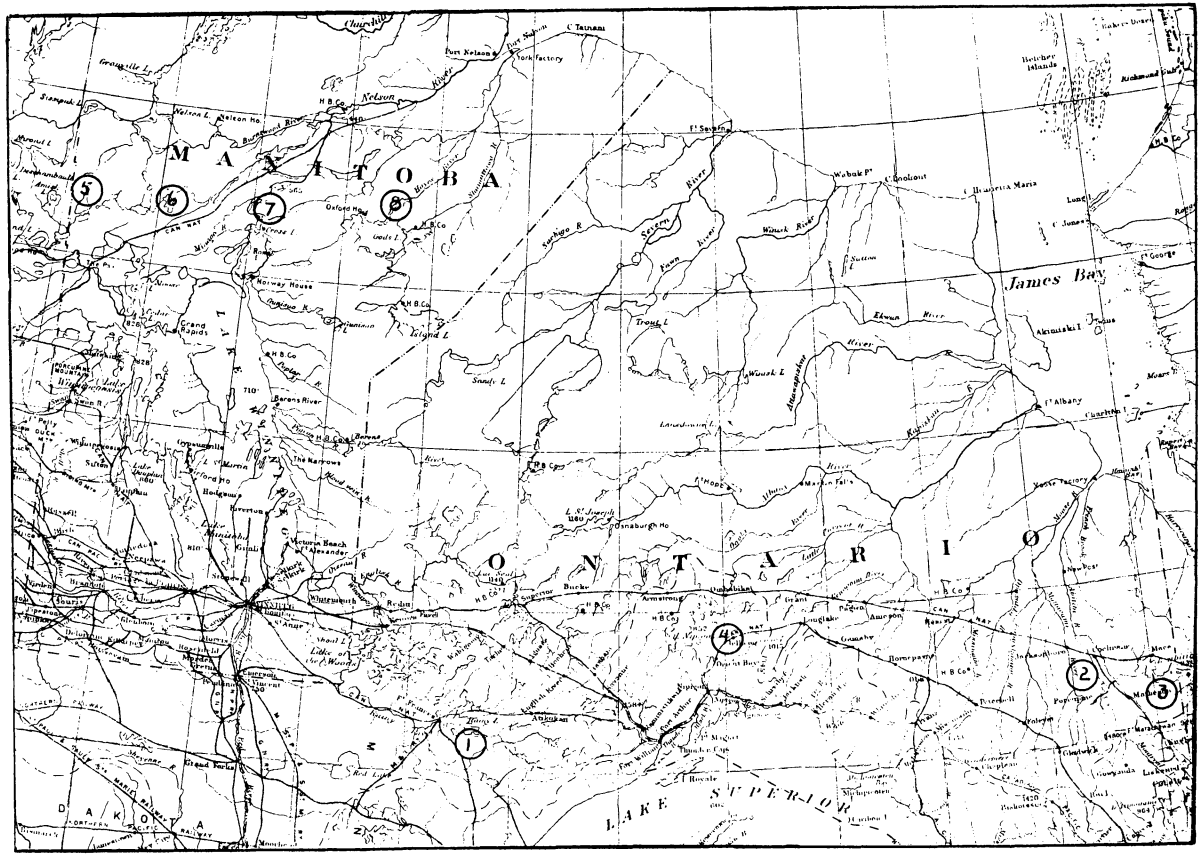

FIG 1

schists, garnetiferous mica schists, hornblende schists, and phyllite.[1] In some of the mica schist, quartz makes up three-fifths of the rock mass, biotite one-fifth, with zoisite the other important mineral present. It seems evident from Lawson's descriptions of the field occurrences and from the results of petrographical examinations and chemical analyses as given in his report, that the rocks are sediments, possibly of somewhat abnormal types. They are entirely clastic; no limestones have been found in association with them. A striking and peculiar circumstance is the lack of coarse sediments or conglomeratic beds in this supposedly thick series. It seems possible that these rocks were formed along the seaward margin of a delta which supplied large quantities of fairly fine débris, the site of deposition for the Coutchiching being so far from shore that no gravels were supplied, but not far enough out to allow the formation of limestones, assuming that conditions were suitable for the deposition of lime rocks at that early period.

The *Keewatin series* consists of: "(1) fine-grained greenstones showing frequently ellipsoidal or amygdaloidal structures or both; (2) coarser-textured greenstones showing neither ellipsoidal nor amygdaloidal structures; (3) greenstone schists of varying degrees of schistosity; (4) rather massive chlorite schists; (5) evenly fissile chlorite schists; (6) irregularly cleaved chlorite schists; (7) black glistening hornblende schists usually on the periphery of the Keewatin belts where they come in contact with granitic intrusions; (8) gray felsite sometimes amygdaloidal; (9) sericitic schists; (10) various stratified grayish-green schists, probably ash beds; (11) agglomerates; (12) gray siliceous slates and schist; (13) banded cherts; (14) mica schists; (15) limestone."[2]

This group is clearly made up for the most part of lava flows and their derivatives with minor amounts of sediments interbanded with the igneous rocks. In summary, then, it may be said that the Coutchiching consists chiefly of sediments, with possibly some beds, such as the hornblende schists, of igneous origin; the Keewatin series is chiefly igneous, with minor sedimentary beds intercalated with the lava flows. There seems

[1] Lawson, *Memoir 40, Geol. Survey of Canada*, p. 28.

[2] *Ibid.*, p. 35.

to have been no erosion period between the formation of the two series.

Lawson considered the Coutchiching to be a distinct series underneath the Keewatin, but the international committee to revise the classification of pre-Cambrian formations did not agree. In some of the areas examined rocks mapped as Coutchiching in the original work were found to belong to the Seine series, which lies with a great unconformity above the Keewatin. Mistakes of this kind are quite to be expected in determining somewhat similar series under the difficult conditions of the original mapping. Lawson, in his later publication, *Memoir 40, Geological Survey of Canada*, admits these mistakes, but still maintains that there is a great sedimentary series below the Keewatin. Some competent observers who have visited the area agree with him.[1] The point has also been raised that the Coutchiching may not be the oldest formation, but may be similar to the interbedded sediments—(12) in the Keewatin—and that beneath the Coutchiching again there may be still older lava flows. If so, it is argued, the Coutchiching series may quite logically be included as part of the Keewatin.

PORCUPINE DISTRICT

The earliest rocks in the Porcupine district of northern Ontario consist of pillow lavas with schists derived from them, "carbonate" rocks of doubtful origin, iron formation, and some fragmental rocks of doubtful character.[2] A group of undoubtedly sedimentary rocks is correlated by Burrows with the Temiskaming series. They consist of "conglomerate, interbanded slate and greywacké, and quartzite." The relations of these sediments to the Keewatin group are shown by the following quotations:

> A contact of the sedimentary rocks with the volcanic rocks can be seen immediately south of the open pit at the Dome mine. Fragments of the volcanic series are abundant in the sedimentary series, and it is likely that the conglomerate has been deposited on the surface of the volcanic series of the Keewatin. . . . . However, one half a mile north west of the north end of

[1] Private Communications, F. J. Alcock and T. L. Tanton.

[2] A. G. Burrows, "The Porcupine Gold Area," *Third Ann. Rept. Ont. Bureau of Mines*, Vol. XXIV, Part III (1915).

Porcupine lake in lot 11 in the fourth concession of Whitney there is a contact of the sedimentary series with pillow lava in which the relationship suggests an igneous contact, that is that the pillow lava is later than the sedimentary rock. It is therefore probable that some of the pillow lavas mapped with the Keewatin are later in age than the Temiskaming series.

While there is much evidence pointing to a separate sedimentary series of rocks the possibility of some of what has been called Keewatin being contemporaneous with the Temiskaming or of some of the sediments being of Grenville age must be considered. Toward the southwest from the open pit at the Dome mine there is a narrow band of conglomerate which has been mapped at Temiskaming. Much of the material in this band immediately north of the readily recognized pillow lava and amygdaloidal rock resembles volcanic fragmental or agglomerate. There is no break, however, between the apparent volcanic fragmental and the interbedded slate and greywacke which occur along the south margin of the open pit and which can be followed northward for a mile. If the rock above mentioned is a volcanic fragmental, and not a true conglomerate deposited on an eroded surface, then there is reason for considering the pillow lavas, fragmental rocks, slates, greywacké and conglomerate as belonging to one series. For lithological reasons it seems preferable to consider the large area of sediments as a separate series.

It is apparent that Burrows recognized the possibility of an interbedded series of sediments and volcanics, but that he decided to correlate the sedimentary part of the series with the lithologically similar Temiskaming rather than accept an alternative hypothesis of a great continuous series made up of lava flows, volcanic fragmentals, and true sediments. The evidence for an erosional unconformity between the volcanics and sediments does not seem to be conclusive.

ABITIBI DISTRICT

The district south of Lake Abitibi has recently received considerable attention, and an interesting series of rocks has been found.[1] Lava flows which are classed as Keewatin are exceptionally well developed, and the scoriaceous surfaces of successive flows make it possible to determine the top and bottom of the formations. Sediments are associated with these lavas. The following is a quotation from the report mentioned:

[1] C. W. Knight, A. G. Burrows, P. E. Hopkins, and A. L. Parsons, "Abitibi Night Hawk Gold Area," *Eighteenth Ann. Rept. Ont. Bureau of Mines*, Part II (1919).

In our map sheet there is an interesting series comprised of highly altered sediments which are closely associated with the Keewatin. . . . . One belt has an apparent thickness of one and one half miles and a length of 11 miles. . . . .

The rocks in the three large areas mentioned in the preceding paragraph consist of slate, greywacké, quartzite, and a little conglomerate, all of which have been altered to schists. Both the cleavage and bedding of the sediments have nearly vertical dips, but there are usually small angles between their strikes. A little chert is also present. Conglomerate schist was seen in four localities and, in each case, near the outer edge of the sediments. . . . . The pebbles which are somewhat flattened, consist of quartz porphyry and greenstones, suggesting an unconformity between the sediments, on the one hand, and the greenstones and quartz porphyry on the other. However, the only good contacts which were seen between the sediments and the greenstones were on lot 7 in the second concession of Coulson township and these might suggest that the sediments were interbedded with the pillow lavas of the Keewatin. It may be added that in this locality the banded cherts which appear to be a part of the main group of sediments are older than the pillow lavas. In view of these apparently conflicting observations it is seen that the relationship between the Keewatin lavas and these old sedimentary rocks has not been definitely worked out. Possibly the conglomerates may be of interformational origin or may belong to the Temiskaming series.

It seems clear that there are two possibilities. Either the lava flows here called Keewatin are in reality much younger than those usually classed as Keewatin, younger in fact than the Temiskaming series, or there is a great interbanded series of lava flows, tuffs, and sediments. The presence of conglomerate in such a series is quite to be expected.

LAKE NIPIGON DISTRICT

In the Kowkash area east of Lake Nipigon, Hopkins[1] has found a series of rocks which he calls the Marshall Lake series. This group consists of quartz-mica schists, garnet, and staurolite schists. Hopkins says:

The chemical composition, microscopic evidence, and frequent occurrence of alternating coarse and fine bands in these quartzose rocks suggest that they are clastics or volcanic fragmental rocks deposited in water. Since they are interbanded with ellipsoidal lavas on Cross lake and contain some iron formation they are apparently closely associated with the Keewatin.

[1] *Ann. Rept. Ont. Bureau of Mines*, Vol. XXVI (1917), p. 206.

No evidence is given for considering these rocks as volcanic fragmental types, and judging from the description they seem to be normal fine-grained clastic sediments.

Along the Canadian Northern Railway east of Lake Nipigon,[1] Burrows found a complex of igneous and clastic rocks, all of which he grouped tentatively as Keewatin. Concerning them he says:

> The age relationship between the mica and quartzose schists of sedimentary origin and the pillow lavas and other igneous rocks is not known. For the most part the sedimentary rocks stand so nearly in a vertical attitude that their relationship cannot be determined. It seems advisable to group all these rocks with the Keewatin until information is available to show that the sedimentary rocks may possibly be older than the lavas.[2]

Both Burrows and Hopkins classify certain other conglomerate rocks as Temiskamian, but in neither area are the conglomerates found definitely unconformable with the lavas. The correlation is a lithological one in both cases, the later age being assumed from the presence of pebbles of jasper, greenstone, and granite in the conglomerate beds.

PRE-CAMBRIAN SECTIONS IN MANITOBA

Various sections in northern Manitoba have been examined in some detail, and a strip of country extending almost across the province has been mapped. Beginning at the Saskatchewan boundary, where the pre-Cambrian basement emerges from beneath the Paleozoics, a series of three map sheets extends eastward to the Hudson's Bay Railway. Northeast of Lake Winnipeg two areas—the Cross Lake district and the Knee-Oxford Lake district—have been studied.

In the most westerly section the oldest rocks are ellipsoidal greenstone and derived schists.[3] Supposedly later than these is a thick series known as the Kisseynew gneiss, a garnetiferous, quartz-biotite gneiss apparently sedimentary in origin. There is also a group of slates, quartzites, and conglomerates. The latter are quite evidently the result of torrential deposition probably in

[1] *Ann. Rept. Ont. Bureau of Mines*, Vol. XXVI (1917), p. 232.

[2] *Ibid.*, p. 239.

[3] *Mem. 105, Geol. Survey of Canada.*

river flood plains. This group, the lower and upper Missi formations, are, however, on structural evidence, thought to be separated by a mountain-making and erosional interval from the volcanic rocks and are therefore not considered in this discussion of the early pre-Cambrian formations.

In the Wekusko (Herb) Lake district, approximately seventy-five miles east of the Saskatchewan-Manitoba boundary, ellipsoidal lavas occur which are apparently the continuation, so far as lavas can be continuous, of the area just described. They are lithologically similar and outcrop practically continuously across the interval. Quartz-biotite gneisses lithologically similar to the Kisseynew gneiss are associated with them. Staurolite schist, conglomerate, slate, and acid volcanic flows also occur. All these are interbanded with the basic ellipsoidal flows.

Alcock's summary[1] is very definite with regard to the relations and character of these early rocks:

> The pre-granite complex is interpreted, therefore, as representing a series of interbanded sediments and volcanic rocks of varying composition. Though the sedimentary division contains members which have pebbles of granite, quartz, and volcanic rocks, no evidence was found that these pebbles were derived from any rocks now exposed in the area, nor was any evidence found, aside from the presence of these bowlders and pebbles, which would suggest that the members containing these fragments represent a younger series infolded with the complex and separated from it by an erosional unconformity. The whole group is regarded as a series of flows and contemporaneous sediments. The absence of limestone, the dominance of clastic sediments, the irregularity of the beds, the great thicknesses locally, the recurrence of conglomeratic horizons, point to a continental rather than to a marine origin for the series.[2]

At Cross Lake, an expansion of the Nelson River below Lake Winnipeg, a series of sedimentary rocks consists of para-gneiss, arkose, and conglomerate; some of the gneisses are garnetiferous. Greenstone, which in places is ellipsoidal, occurs in the area. The sediments are interbanded with the lavas. They are interpreted as continental, probably fluviatile deposits.[3]

[1] F. J. Alcock, *Memoir 119, Geol. Survey of Canada.*

[2] *Ibid.*, p. 24.

[3] F. J. Alcock, *Summary Report, Geol. Survey of Canada*, Part D (1919).

Eastward across the divide on the headwaters of the Hayes River, early pre-Cambrian rocks are exposed at Knee Lake and Oxford Lake.[1] A lower, dominantly sedimentary part, consists of rusty weathering garnetiferous biotite gneiss, impure quartzite, slate, conglomerate, tuffaceous rocks, and some interbedded flows. The thickness is probably several thousand feet. Above the dominantly sedimentary group are flows of ellipsoidal weathering lavas together with a few bands of iron formation. These groups are apparently merely parts of a great continuous series. The sediments are in great part typical continental deposits.

COMPARISON OF THE FORMATIONS

From the descriptions of the various areas quoted it is clear that there are two distinct types of rocks in the early formations: (1) volcanic flows now altered to greenstone and chlorite schist, and (2) sedimentary rocks consisting largely of gneiss but also in places including slate, quartzite, and minor amounts of conglomerate. The gneisses retain evidences of bedding although in many occurrences metamorphism has destroyed some of the original texture. Analyses of specimens of these old gneisses are comparable to analyses of typical sediments. The slates commonly show the original bedding as color variations at slight angles to the fissility. Some arkosic rocks still retain the cross bedding and ripple-markings of the original sands and conglomerate, even though the matrix may be thoroughly schistose, with complete recrystallization of the constituent minerals, and are still recognizable as water-laid clastic rocks.

The peculiarities of all the sedimentary formations of this early period are the comparatively small amount of conglomerate and the complete lack of limestone. The sediments found in Manitoba are continental deposits probably formed under deltaic or piedmont conditions. The lack of any large amount of coarse material is evidence that no high land masses existed near the site of deposition, but the ripple-marking and cross-bedding of some of the rocks indicate shallow-water conditions during the formation of some of the beds. The early sediments in other areas

[1] E. L. Bruce, *Summary Report, Geol. Survey of Canada*, Part D (1919).

are similar to those in Manitoba, and it may be assumed that they were formed in much the same way.

The volcanic rocks are lithologically similar throughout the whole region discussed, and this striking similarity quite naturally has led to the correlation of these rocks wherever they occur. The flows are ellipsoidal or massive greenstone of medium basicity. Many of them are now altered to schists. Along with these, minor thicknesses of acidic flows and tuffaceous beds occur. In many districts thin sedimentary beds are found with the igneous rocks. Banded iron formation is very commonly associated with the flows of basic composition.

Although the rock types are comparable, the age relations are variable. In some districts the sedimentary rocks lie above the volcanics. In others the two are interbanded, and in others the greater thickness lies below the igneous rocks. No erosion interval has been recognized; the separation into igneous and sedimentary divisions made in some localities, is purely arbitrary, and implies simply that the divisions are dominantly clastic or dominantly igneous. For in most occurrences there are sedimentary beds among the igneous rocks and flows intercalated with the sediments.

CLASSIFICATION

None of the general classifications of pre-Cambrian formations is applicable to this early complex. The classification[1] accepted by the International Committee places the Keewatin as the lowest formation and does not recognize the presence of great thicknesses of clastic sediments below the great unconformity at the base of the Huronian, nor Lawson's Coutchiching as a great series below the igneous flows. There are, however, not only in the Rainy River district, but in other districts, thick sedimentary formations below the oldest lava flows recognized in those districts. It is possible, as suggested, that other older lava flows exist beneath the sediments, but if so, the application of the term Keewatin, if it is to be retained, must be extended to include a large amount of sedimentary rocks.

[1] *Jour. of Geol.*, Vol. XIII (1905), pp. 89-104.

On the other hand, the original classification suggested by Lawson, in which the sedimentary Coutchiching is the oldest formation, cannot be applied to those successions in which the sediments are interbanded with lava flows or even lie above rocks which are lithologically similar to the Keewatin.

From theoretical considerations it seems unlikely that any of these formations can be used to correlate successions in different districts. Commonly the basic flows have been used in this way. Since they are lavas, it is impossible that any one eruption could have extended to any great distance, and hence correlation on the basis of lithology of separate flows must be most uncertain. Nor is this affected by the possibility that many of the flows are subaqueous, as there is no evidence that the bodies of water beneath which the flows may have been extruded were large or continuous. In fact, in some instances the interbedding of ellipsoidal flows and shallow water or terrestrial sediments is evidence that the bodies of water were limited in area and of brief duration. Correlation by means of the sedimentary beds is even less reliable. The conglomerate, slate, and gneiss of this early period are believed to be almost entirely of terrestrial or shallow-water origin. No bed formed in this way could be expected to have great lateral extent, and no determination of age can be made on the ground of its similarity to rocks in other districts.

Since no erosion break has been recognized in any of the successions yet worked out, and since there is this very marked difference in the relations of sedimentary and igneous rocks in various areas, it is plain that no course is possible, at present, except the interpretation of the early part of the pre-Cambrian as a period of volcanic activity in which eruptions of lava alternated with deposition of ordinary clastic sediments. These periods of eruption were recurrent, but not necessarily contemporaneous even in neighboring districts. Hence the succession of volcanic and sedimentary rocks is naturally not the same in any two districts. The result is a great thickness of lavas, tuffs, and sediments, all of which belong to one great period in the earth's history. It is manifestly impossible to apply to rocks of such origin either of the terms Keewatin or Coutchiching and, if the view set forth here be

accepted, it seems necessary to restrict those terms to the original area in which they were applied. If it seems convenient in any other area to divide the rocks of this early period, local names should be applied to the divisions without implying any wide regional correlation. Detailed examination may later make clear the time relations of events, and if so, correlations can then be made. If that ever becomes possible, it seems more than likely that instead of rocks of similar lithology being found to belong to the same period, it will be found that flows in some districts are contemporaneous with sediments in others, or that a period of deposition of sediments in one section corresponds to a period of local erosion in a neighboring section.

Although at present sufficient work has not been done to make correlation possible, it is interesting to note the distribution of the sediments in relation to the igneous rocks. In western Manitoba the sediments lie above the flows. In north central Manitoba flows and sediments are interbedded. In eastern Manitoba and western Ontario the great mass of sediments lies beneath the volcanics. In eastern Ontario the two are again interbedded. These relations can be explained by the presence of a great area of continental deposition extending southward from an old land mass in central Canada in the very earliest times. Over this area, terrestrial and shallow-water deposits were laid down on river plains, piedmont fans, or deltas along whose margin sediments were interbedded with subaqueous lava flows. Still farther out no sediments at all were deposited until a later readjustment of land and water shifted the zone of sedimentation to areas where, previously, only igneous rocks were forming. At the same time the central area became the site of igneous activity and the extrusion of lavas over the clastic sediments already laid down. At present this can be considered only a suggestion resting upon slight field evidence.

SUMMARY

The points raised in the preceding discussion can be settled only by more detailed work, but the following conclusions seem to be warranted from present knowledge:

1. In the early part of the pre-Cambrian, periods of volcanic activity alternated with periods of normal sedimentation. The resulting rocks form one great series.

2. At present local terms only should be used in subdividing this complex. The terms now in use in the generalized classifications are inapplicable, and should be restricted to the areas in which they were used originally.

3. The sedimentary record of the early pre-Cambrian seems to be largely one of continental rather than marine conditions. Some of the deposits were undoubtedly deltaic, others were likely piedmont, lacustrine, fluviatile, and even basin deposits. It points to the conclusion that even from the very earliest pre-Cambrian, the Canadian shield was a positive element.